

VARIABLE-FREQUENCY INVERTER MICROWAVE OVEN AND METHOD FOR
CONTROLLING THE SAME

BACKGROUND OF THE INVENTION

5

Field of the Invention

The present invention relates to variable-frequency inverter microwave ovens and methods for controlling the same, and more particularly to a variable-frequency inverter 10 microwave oven and a method for controlling the same, wherein a constant-level voltage is supplied to a magnetron, which generates electromagnetic waves in the microwave oven, so that a drive duration of the magnetron can be lengthened, thereby 15 improving heating efficiency and reliability of an inverter operation.

Description of the Related Art

Fig. 1 is a block diagram showing the construction of a conventional inverter microwave oven. A description will 20 hereinafter be given of the construction and operation of the conventional inverter microwave oven with reference to Fig. 1.

The conventional inverter microwave oven is a cooking apparatus using dielectric heating, which is a kind of high frequency-based device. The dielectric heating is to radiate 25 microwaves to food received in the oven to vibrate molecules of

water in the food, thereby heating the food. This dielectric heating heats food beginning with the inside thereof in a different manner from common heating methods which heat food beginning with the surface thereof. To this end, the inverter 5 microwave oven typically utilizes microwaves having a wavelength of about 1/10 that of TV broadcast waves.

A magnetron 2, which is a particular two-pole vacuum tube, is used as a heating source for generating microwaves. The magnetron 2 concentrates the microwaves on food through an 10 output antenna to heat the food. An internal space of the oven where the microwaves resonate is called a cavity 1, which includes a turntable for rotating the food to heat it evenly.

The microwave oven further comprises a cooking command input unit (not shown) provided at the outer surface of the 15 oven for enabling a user to input a cooking command, a display unit (not shown) for displaying the remaining time or elapsed time in response to the cooking command inputted through the cooking command input unit, and a door (not shown) for opening/closing the front of the cavity 1.

A commercial alternating current (AC) voltage source 4 is provided to supply a commercial AC voltage of 220V-60Hz to a general home, in which the microwave oven is installed, to drive the magnetron 2. An inverter 3 is also provided to convert the commercial AC voltage supplied from the commercial 25 AC voltage source 4 into a high-power direct current (DC)

voltage of about 4000V or more and supply the converted DC voltage to the magnetron 2. As a result, the magnetron 2 is driven to heat and cook food in the cavity 1.

5 The construction and operation of the conventional inverter microwave oven will hereinafter be described in detail with reference to Fig. 2, which is a functional block diagram of the conventional inverter microwave oven.

10 The conventional inverter microwave oven comprises a DC voltage generator 5 for rectifying and smoothing the commercial AC voltage supplied from the commercial AC voltage source 4 and outputting the resulting DC voltage to a switching device 6. To this end, the DC voltage generator 5 is provided with a bridge diode.

15 The switching device 6 acts to perform a switching operation based on the DC voltage from the DC voltage generator 5 under control of a microcomputer 9 to generate an AC voltage, and output the generated AC voltage to a magnetron drive voltage generator 7. To this end, the switching device 6 includes a plurality of switches turned on/off in response to the DC voltage from the DC voltage generator 5. The magnetron drive voltage generator 7 functions to convert the AC voltage from the switching device 6 into a high-power DC voltage appropriate to the driving of the magnetron 2 and output the converted DC voltage to the magnetron 2.

20

25 The conventional inverter microwave oven further

comprises a protection circuit 8 for measuring the level of the DC voltage from the DC voltage generator 5, inputted to the switching device 6, and, if the measured DC voltage level is higher than or equal to a predetermined threshold voltage 5 level, turning off the switching device 6 to prevent the switches thereof from being damaged. For the convenience of description, the DC voltage generator 5, switching device 6, magnetron drive voltage generator 7, protection circuit 8 and microcomputer 9 are shown in Fig. 2 to constitute the block of 10 the inverter 3.

However, the commercial AC voltage for the home supplied from the commercial AC voltage source 4 has voltage/current characteristics varying with regions/time zones. A DC voltage with a ripple component, generated by the DC voltage generator 5, varies with a variation in the AC voltage, resulting in a 15 variation in an AC voltage generated by the switching device 6 because it performs a switching operation based on the DC voltage. As a result, a high-power DC voltage, generated by the magnetron driving voltage generator 7 according to the AC 20 voltage from the switching device 6, is subject to a variation.

Accordingly, the output power of the magnetron 2, which is a heating source for cooking food, varies with the variation in the commercial AC voltage. For this reason, even though the user inputs the same cooking command, he/she cannot obtain a 25 desired cooking result because the cooked state of food is not

uniform. Consequently, the user has the trouble of having to additionally heat the food.

In other words, the magnetron 2 is driven only when it is applied with a high-power DC voltage of a reference level or 5 more from the magnetron drive voltage generator 7. In this regard, where the magnetron 2 is applied with a DC voltage of less than the reference level due to a variation in the commercial AC voltage, it is not operated as the heating source, leading to a reduction in drive time thereof.

10 The reduction in the drive time of the magnetron 2 in turn results in a reduction in heating efficiency, thereby causing heating power not to be maintained at a constant level. Besides, in the case where the commercial AC voltage abruptly increases or decreases, the switches of the switching device 6 15 may be damaged, resulting in a degradation in durability of a product.

SUMMARY OF THE INVENTION

20 Therefore, the present invention has been made in view of the above problems, and it is an object of the present invention to provide a variable-frequency inverter microwave oven and a method for controlling the same, which can vary a switching frequency of a switching device for AC voltage 25 generation with a variation in a commercial AC voltage supplied

to an inverter to lengthen a drive duration of a magnetron, thereby improving heating efficiency and reliability of the inverter microwave oven and preventing internal devices thereof from being damaged.

5 In accordance with one aspect of the present invention, the above and other objects can be accomplished by the provision of a variable-frequency inverter microwave oven comprising: a magnetron for generating electromagnetic waves; direct current (DC) voltage generation means for rectifying and
10 smoothing a commercial alternating current (AC) voltage to generate a DC voltage, the commercial AC voltage being an inverter drive voltage; switching means for performing a switching operation based on the DC voltage from the DC voltage generation means to generate an AC voltage for the driving of the magnetron, the switching means including a plurality of switches turned on/off in response to the DC voltage from the DC voltage generation means; variable-frequency control means for varying a switching frequency of the switching means according to a level of the DC voltage from the DC voltage generation means to maintain the AC voltage from the switching means at a constant level; and magnetron drive voltage generation means for converting the AC voltage from the switching means into a high-power DC voltage and transferring the converted DC voltage to the magnetron to drive it.

15
20
25

In accordance with another aspect of the present

invention, there is provided a method for controlling a variable-frequency inverter microwave oven, comprising the steps of: a) rectifying and smoothing a commercial AC voltage into a DC voltage; b) varying a switching frequency of a switching device with a variation in the DC voltage; and c) performing a switching operation of the switching device at the varied switching frequency to generate an AC voltage, and driving a magnetron using the generated AC voltage.

10 BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram showing the construction of a conventional inverter microwave oven;

Fig. 2 is a functional block diagram of the conventional inverter microwave oven;

20 Fig. 3 is a functional block diagram of a variable-frequency inverter microwave oven in accordance with the present invention;

Fig. 4 is a circuit diagram of a variable-frequency controller in Fig. 3;

25 Figs. 5a to 5c are waveform diagrams of voltages and

5 frequencies generated in the conventional inverter microwave oven and the present variable-frequency inverter microwave oven;

10 Figs. 6a and 6b are waveform diagrams of switching device output voltages and magnetron drive voltages generated in the conventional inverter microwave oven and the present variable-frequency inverter microwave oven; and

15 Fig. 7 is a flow chart illustrating a method for controlling the variable-frequency inverter microwave oven in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 Fig. 3 is a functional block diagram of a variable-frequency inverter microwave oven in accordance with the present invention. As shown in this drawing, the variable-frequency inverter microwave oven comprises a commercial AC voltage source 10 for supplying a commercial AC voltage of 220V-60Hz, a magnetron 30 for generating electromagnetic waves, and an inverter 20 for generating a high-power DC voltage, or a magnetron drive DC voltage, of 4000V or more according to the commercial AC voltage supplied from the commercial AC voltage source 10 and applying the generated high-power DC voltage to the magnetron 30 to drive it so as to heat and cook food in the microwave oven.

The inverter 20 includes, as shown in Fig. 3, a DC voltage generator 22 including a bridge diode and serving to rectify and smooth the commercial AC voltage from the commercial AC voltage source 10 to generate a DC voltage, and a 5 switching device 23 for performing a switching operation based on the DC voltage from the DC voltage generator 22 to generate an AC voltage. To this end, the switching device 23 has a plurality of switches turned on/off in response to the DC voltage from the DC voltage generator 22.

10 The inverter 20 further includes a variable-frequency controller 24 for varying a switching frequency of the switching device 23 according to the level of the DC voltage from the DC voltage generator 22 to maintain the AC voltage from the switching device 23 at a constant level, and a 15 magnetron drive voltage generator 29 for converting the constant-level AC voltage from the switching device 23 into a high-power DC voltage appropriate to the driving of the magnetron 30 and apply the converted DC voltage to the magnetron 30 to drive it.

20 Note that the commercial AC voltage supplied from the commercial AC voltage source 10 may have different values according to different countries or regions although it has been disclosed herein to have the value of 220V-60Hz. In addition, although the DC voltage required for the driving of 25 the magnetron 30 has been disclosed to be 4000V or more, it may

be set to different values according to different manufacturers.

The inverter 20 further includes a drive current sensor 21 for sensing a variation in the commercial AC voltage supplied from the commercial AC voltage source 10, namely, a variation in input drive current to the inverter 20, and a protection circuit 26 for, if the level of the DC voltage from the DC voltage generator 22 is higher than or equal to a predetermined threshold voltage level, turning off the switching device 23 to prevent the switches thereof from being damaged.

The inverter 20 further includes a microcomputer 27 for controlling the output power of the microwave oven in response to a cooking command inputted through a cooking command input unit provided at the outer surface of the oven and outputting a control signal in response to the variation in the drive current sensed by the drive current sensor 21 to vary the switching frequency of the switching device 23 correspondingly to the sensed drive current variation.

The inverter 23 further includes a transformer 28 connected between the switching device 23 and the magnetron drive voltage generator 29. The transformer 28 has a turn ratio of 1:20 to 1:40 as in the general inverter microwave oven. The AC voltage, generated according to the switching operation of the switching device 23, is thus boosted 20 to 40 times based

on the turn ratio of the transformer 28.

Therefore, the AC voltage generated by the switching device 23 is boosted to a high level through the transformer 28 and applied to the magnetron drive voltage generator 29, which 5 then converts the applied high-level AC voltage into a high-power DC voltage and applies the converted DC voltage to the magnetron 30.

The variable-frequency controller 24 is adapted to vary the switching frequency at which the switches of the switching 10 device 23 are turned on/off, according to the level of the DC voltage from the DC voltage generator 22. That is, if the level of the DC voltage from the DC voltage generator 22 is lower than a predetermined reference level, the variable-frequency controller 24 lengthens a high-level duration of a drive pulse 15 to the switching device 23. As a result, the switching device 23 performs the switching operation based on the DC voltage from the DC voltage generator 22 for the lengthened high-level duration of the drive pulse, so as to output a higher AC voltage.

20 To the contrary, if the level of the DC voltage from the DC voltage generator 22 is higher than the predetermined reference level, the variable-frequency controller 24 shortens the high-level duration of the drive pulse to the switching device 23. As a result, the switching device 23 performs the 25 switching operation based on the DC voltage from the DC voltage

generator 22 for the shortened high-level duration of the drive pulse, so as to output a lower AC voltage.

In this manner, in the case where the DC voltage from the DC voltage generator 22 is lower in level, the switching device 23 generates an AC voltage corrected to a higher level under the variable-frequency control of the variable-frequency controller 24 and transfers the generated AC voltage to the magnetron 30 through the transformer 28 and magnetron drive voltage generator 29, thereby raising the heating power of the magnetron 30.

Similarly, in the case where the DC voltage from the DC voltage generator 22 is higher in level, the switching device 23 generates an AC voltage corrected to a lower level under the variable-frequency control of the variable-frequency controller 24 and transfers the generated AC voltage to the magnetron 30 through the transformer 28 and magnetron drive voltage generator 29, thereby lowering the heating power of the magnetron 30. Consequently, the heating power of the magnetron 30 is maintained at a constant level.

Fig. 4 is a circuit diagram of the variable-frequency controller 24 in Fig. 3.

As shown in Fig. 4, the variable-frequency controller 24 includes a DC voltage input node 24a for receiving the DC voltage from the DC voltage generator 22 inputted thereto, a current source 24b for generating current based on the DC

voltage inputted to the DC voltage input node 24a, and an integrated circuit 24c for varying the switching frequency of the switching device 23 according to the amount of the current from the current source 24b. The current source 24b is
5 provided with one or more resistors R24a and R24b.

The integrated circuit 24c is typically used for the variable-frequency control and adapted to vary the width of its output pulse with the amount of input current thereto. If the amount of the current from the current source 24b is
10 smaller, the integrated circuit 24c widens the width of its output pulse and outputs the resulting lower-frequency pulse. To the contrary, if the amount of the current from the current source 24b is larger, the integrated circuit 24c narrows the width of its output pulse and outputs the resulting higher-
15 frequency pulse.

The variable-frequency controller 24 further includes a transistor T24 having its base connected to the current source 24b, its collector connected to the integrated circuit 24c and its emitter connected to a resistor R24c. With this configuration, the amount of current at the collector of the transistor T24, which is determined depending on the amount of current at the base of the transistor T24, is applied to the integrated circuit 24c for the variable-frequency control.
20

Fig. 5a shows a waveform G1 of an output voltage from the switching device 23 under the condition that the variable-
25

frequency control operation of the present invention is not performed, as in the conventional inverter microwave oven. The waveform G1 of Fig. 5a schematically represents only an envelope of the AC voltage generated from the switching device 23 for the purpose of waveform comparison.

As shown in Fig. 5a, the envelope waveform G1 of the AC voltage generated by the switching operation of the switching device 23 has a period of 8ms and a peak level of about 170V. This envelope waveform G1 follows a waveform G0 of the input 10 DC voltage to the switching device 23 as shown in Fig. 5b.

For example, provided that the output voltage from the switching device 23 must be at least 100V for the driving of the magnetron 30 in the inverter microwave oven, the magnetron 30 is not driven in shaded areas (0 through less than 100V) of the start and end portions of the envelope waveform G1, so it 15 is used as a heating source for only a drive time T as shown in Fig. 5a.

In other words, as compared with the output voltage from the switching device 23, the drive time T of the magnetron is 20 not sufficient, thereby reducing drive efficiency of the magnetron, or heating efficiency.

The waveform G1 of the output voltage from the switching device 23 follows the waveform G0 of the DC voltage with a ripple component, supplied from the DC voltage generator 22 to 25 the switching device 23. The DC voltage from the DC voltage

generator 22 is a rectified/smoothed version of the commercial AC voltage with a real-time variation. In this regard, the waveform G1 of the output voltage from the switching device 23 varies with the variation in the commercial AC voltage and the 5 drive time T of the magnetron thus varies, thereby making it impossible to obtain stable output power.

Fig. 5b shows a frequency Hz that the variable-frequency controller 24 outputs to control the switching frequency of the switching device 23 according to the waveform G0 of the 10 input DC voltage to the switching device 23.

That is, the variable-frequency controller 24 outputs a highest frequency of about 27000Hz at a peak level of 170V of the input DC voltage to the switching device 23, and a lower frequency of about 16000Hz at a level of 40V of the input DC 15 voltage. In this manner, the variable-frequency controller 24 generates a frequency corresponding to the level of the DC voltage from the DC voltage generator 22 and outputs the generated frequency to the switching device 23 to vary the switching frequency of the switching device 23 so that the 20 switching device 23 can generate a constant-level AC voltage and the magnetron 30 can thus have a constant-power value.

Fig. 5c shows a waveform G2 of an output voltage from the switching device 23 based on the variable-frequency control of the variable-frequency controller 24 as shown in 25 Fig. 5b. The waveform G2 of Fig. 5c and the waveform G1 of

Fig. 5a, not based on the variable-frequency control, are compared as follows.

As shown in Fig. 5c, the shaded areas of the waveform G1 of Fig. 5a, or periods in which the magnetron 30 cannot be driven, are shortened under the variable-frequency control. The reason is that, under the variable-frequency control, voltage levels of the shaded areas of the waveform G1 are raised and a ridge of the waveform G1 having the peak level is thus flattened, which leads to the conversion of the waveform G1 into a square waveform such as the waveform G2.

Accordingly, the drive time T of the magnetron 30 in Fig. 5a is lengthened to become a drive time T' in Fig. 5b, thereby increasing the heating efficiency. Besides, even when the peak level of the input DC voltage is raised due to an abrupt increase in the commercial AC voltage, it is limited to a desired value under the variable-frequency control, thereby preventing the switches of the switching device 23 from being damaged.

Fig. 6a shows a waveform G1' of the output AC voltage from the switching device 23 corresponding to the waveform G1 of Fig. 5a, experimentally obtained under the condition that the variable-frequency control operation of the present invention is not performed, as in the conventional inverter microwave oven.

The waveform G1' of Fig. 6a corresponds to the AC

voltage generated by the switching device 23 on the basis of the DC voltage from the DC voltage generator 22 without the variable-frequency control. The lower waveform $G1''$ of Fig. 6a corresponds to a magnetron drive voltage generated according to the AC voltage from the switching device 23.

As shown in Fig. 6a, the magnetron drive voltage is maintained at the level of 4000V for only 4ms of one period, 8ms, as indicated by a solid line of the waveform $G1''$. This duration of 4ms is equal to the magnetron drive time T .

The upper waveform $G2'$ of Fig. 6b corresponds to a square-wave AC voltage of 120Hz outputted from the switching device 23 after the variable-frequency control is performed, and the lower waveform $G2''$ corresponds to a magnetron drive voltage generated according to the square-wave AC voltage.

As shown in Fig. 6b, the magnetron drive voltage is maintained at the level of 4000V for 7ms of one period, 8ms, as seen from the waveform $G2''$. This duration of 7ms is equal to the magnetron drive time T' in Fig. 5c. Therefore, according to the present invention, the magnetron drive time is increased from the conventional value, 4ms, to 7ms on a period basis, resulting in an increase in the magnetron drive efficiency of the microwave oven, or the heating efficiency, with respect to the input voltage.

Fig. 7 is a flow chart illustrating a method for controlling the variable-frequency inverter microwave oven in.

accordance with the present invention.

First, a commercial AC voltage supplied to the home is rectified and smoothed into a DC voltage of 120Hz with a ripple component (S1).

5 At this time, the internal devices of the microwave oven may be damaged due to an abrupt increase or decrease in the commercial AC voltage resulting from a real-time variation therein. In order to avoid this problem, the level of the DC voltage is compared with a predetermined threshold voltage level (S2). If the level of the DC voltage is higher than or 10 equal to the predetermined threshold voltage level, the inverter circuit operation is forced to be shut down to protect the internal devices.

15 In the case where the level of the DC voltage is lower than the predetermined threshold voltage level, a different amount of current based on a variation in the DC voltage level is applied to the integrated circuit of the variable-frequency controller (S3).

20 The variable-frequency controller varies a switching frequency of the switching device according to the amount of current applied thereto to determine a switching operation of the switching device (S4).

At this time, if the level of the DC voltage is lower than a predetermined reference level, the switching frequency 25 of the switching device is lowered. However, in the case where

the level of the DC voltage is higher than the predetermined reference level, the switching frequency of the switching device is raised. In this manner, the variable-frequency control is performed.

5 Thereafter, the switches of the switching device are turned on/off at the switching frequency based on the variable-frequency control, thereby enabling the magnetron drive voltage generator to generate a constant-level magnetron drive voltage to drive the magnetron (S5).

10 As apparent from the above description, the present invention provides a variable-frequency inverter microwave oven and a method for controlling the same, wherein a switching frequency of a switching device is controlled in a variable manner according to the level of an input DC voltage to the switching device so that the switching device can generate a square-wave AC voltage. Therefore, a drive duration of a magnetron is lengthened compared with a conventional one, thereby improving heating efficiency of the microwave oven. Further, a peak level of the AC voltage from the switching device is limitedly raised with an abrupt increase in the input DC voltage under the variable-frequency control, whereby internal devices of the microwave oven can be protected to guarantee stability thereof.

15 20 25

Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those

skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.